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SEMI - ANNUAL STATUS REPORT NO. 2 ON SPECTROSCOPIC STUDY OF SOLAR AND PLANETARY ATMOSPHERES

August 1, 1963 to February 1, 1964

WORK DONE UNDER NASA GRANT
NsG - 362

PREPARED BY:

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SEMI-ANNUAL STATUS REPORT NO. 2 TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

"SPECTROSCOPIC STUDY OF SOLAR AND PLANETARY ATMOSPHERES"

NAME AND ADDRESS OF INSTITUTION: GEORGETOWN UNIVERSITY
WASHINGTON 7, D.C.

PROJECT DIRECTOR : Dr. Francis J. Heyden, S.J.

ASSISTANT SCIENTIFIC DIRECTOR: Dr. Carl C. Kiess

I. Work Done: During the period covered in this report the major part of the work was in refining the method of observation and analysis of the data. In general, this was done in order to present our findings in the best available manner. In some instances this necessitated changes in the method or even a completely different attack. However, we feel that these refinements were necessary and important to the investigation and would have to be done to present the findings in an acceptable manner.

The three areas of research are principally the same. The first involves the preparation of the simulated Martian Atmosphere. The second is a study of the spectrum of Jupiter from high dispersion plates. These plates were taken on the Georgetown spectrograph with the aid of the twenty-three and one half inch flat : corrected to 1/4 to 1/8 wave length. The third is concerned with the observation of planets at every available opportunity along with spectrum analysis, i.e. plate reduction and analysis of data.

Area 1. Laboratory Spectra - Simulated Martian Atmosphere. This phase of the investigation remained the same except for a more detailed study in each data group. This study is scheduled into the following parts or "data groups."

1. Spectrograms of molecular bands of NO_2 in white light in the regions from 3500 A to 6500 A and their identification... These plates are taken using the black-body as source for a temperature of 0° C at 2.7 mm atmospheres.

Six spectra are on each plate:

a) black-body spectrum
b) four absorption spectra of differing exposure times
c) iron reference spectrum

A comparison of these spectra facilitates the study of strong and weak bands.

2. Spectrograms of the sun. Plates are exposed with the sun as the source instead of the black-body as in group No. 1 above.

3. Intensity study of the absorption bands of NO_2 are made from plates obtained in each eavelength region containing:

a) black-body spectrum
b) spectrum of NO_2 using black-body light source
c) spectrum of the sun
d) spectrum of NO_2 using sun as a light source

These intensity standards are put on all of the plates in this investigation. The source is the black-body and the varying intensities are accomplished by mounting a sector wheel at the slit. Thus all of the plates may be reduced to the same background or standard by which intensity can be determined for each desired wave length.

4. Microphotometric tracings of the various spectra in each group. These tracings are made with a narrow slit and the highest variation peak to zero allowed by the width of the chart. The chart is set on the maximum available speed. This arrangement allows for maximum area under the curve or trace. This feature in minimixing error is an essential factor in this method of analysis.

5. Measurement of all band heads and distinguishing features, with telereadex projection type measuring engine correlates microphotometor tracings with known standards and wave lengths.

6. The determination of the threshold or minimum will be used for verification of Nitrogen Bands in planetary spectrograms.

7. A study in comparison between Martian spectral data and the Laboratory NO_2 data.

Figures 1 and 2 are examples of the microphotometric tracings showing an absorption region of NO_2 for varying pathlengths. It should be noted that for constant T the intensity of absorption becomes more pronounced with increased pressure in the tube. This study is in progress. Each band will be traced and identified in this manner. There also may be seen the lower limit for this band detection or its threshold.

Previously the method of analysis to present a quantitative picture of intensities of absorption by NO_2 in the laboratory was as follows:

1) A blackbody comparison tracing is superimposed on a blackbody plus NO_2 tracing, and the former is traced accurately in pencil upon the latter. 2) A ruler is slid along the chart, and the linear difference between (blackbody plus NO_2) and (blackbody alone) is noted and graphed, at random wavelengths with an interval of about one Angstrom per point. 3) Each (blackbody plus NO_2) minus (blackbody alone) curve is transposed to a bond paper in 50 Angstrom segments. 4) The total pathlength for each 50 Angstrom region is listed in Table 1. Some regions will have more curves than others, depending on availability of good data in the particular region. 5) A ruler is slid along the wavelength scale, and the intensity of absorption is determined on an arbitrary scale in a downward direction, for each curve, at each wavelength from 4,250 A to 4,700 A (Angstrom by Angstrom), and every second wavelength (every two Angstroms) is noted for the region 4,700 A to 5,100 A. All intensities at a given wavelength for all curves are added to get a total intensity y_λ. 6) Each intensity is normalized to a scale from zero to ten, the smallest absorption in a 50 A region being zero and the largest absorption in the 50A region being ten. The formula for determining these values is:

$$y_N = 10 \frac{y_\lambda - y_m}{y_M - y_m}$$

where: y_λ = the sum of absorption intensities of an arbitrary scale at wavelength λ.

y_M = the sum of absorption intensities on the same arbitrary scale at the wavelength of maximum absorption in the given 50 A region.

y_m = the sum of absorption intensities on the same arbitrary scale at the wavelength of minimum absorption in the given 50 A region.

y_N = value of the absorption intensity at wavelength λ normalized to a scale of 0 - 10 for the 50 A region.

This method is adequate but manifests some difficulties. It is time consuming and is prone to personal error in the point for point plot. The construction of the curve is a somewhat questionable method in the analysis. The primary objection is that the information obtained in each spectral range is limited to that region. That is the intensities of one region or band can not be compared with any other range. Thus we felt that a more precise and flexible analysis should be made.

The analysis in progress utilizes the Telereadex and E 101 computer thereby eliminating all the arduous hand work. In general a microphotometer tracing of the Band region is placed on the Telereadex and projected on the measuring table. The area is magnified five times. The x, y coordinates of each profile are recorded on tape by the flexowriter. These tapes are run on the E 101, which has been programmed to determine the area under the curve by Numerical Integration. Therefore this area is proportional to the number of transitions or absorption This will allow, after calibration of the plate, a direct comparison with any region of the spectrum. Analysis of the previous method may be seen in figure 3 where the NO_2 Lab curve on the bottom resembles the Mars-Moon graph. However, the new method will be more revealing since it is a direct method and thus more meaningful.

Therefore in this area we are directing our efforts to obtaining data for area analysis.

Area 2 Spectrum of Jupiter from High Dispersion Plates.

Twenty-four sets of plates were taken of Jupiter's spectrum. Each set consists of a 103aO and a 103aD plate. The region covered extends from 3200 A to 6000 A. In general the planetary spectrum was not visible below 3900 A. The spectrum of the moon or sun was taken on each plate for comparison purposes. Fourteen observations were made of Venus. Sets of 103aO and 103aD plates were used for ten of them and four used 103aJ plates with longer exposures to obtain the spectrum farther into the ultra-violet.

All observations were made at Georgetown College Observatory with the high dispersion spectrograph located approximately fifty yards east of the main observatory. A 15,000 line per inch original Wood concave grating was used in a Wadsworth mounting. Dispersion was five angstroms per millimeter. A slit width of fifty microns was used for all exposures except the last one of Jupiter when one hundred microns was used.

The analysis of the plates has thus far been confined to the 103aD plates of Jupiter. Microdensitometer tracings were made of many of the plates and the tracings analysed for differences between the planetary and solar spectra. The plates are examined for band heads and band structure using the projection type measuring engine.

The differences are obtained by plotting mean values of the microdensitometer tracings, planetary and solar, at some interval (4 A. here) and then plotting their difference, point by point. Figure 1 shows a portion of two tracings and figure 2 shows a 4 A plot of two entire tracings and their difference. Those differences which appear repeatedly are examined further by making new tracings using a higher chart speed, thus affording a more accurate tracing of the region. See figure 3. This type of analysis shows six new weak absorption features in the 5000 A. to 6000 A region. Also seen are two previously identified methane bands.

Four of these absorption features have been tentatively identified as methane bands. No identification has been made of the remaining two. One of them coincides with a methane band but it is probably due to something else since the vibrational transition involved if it were methane is a weak one.

Further study is needed to make a positive identification of the observed features. The 103aO plates have to be analysed as well as the Venus plates.

Absorption Features in the 5000 A. - 6000 A. Region

Wavelength	Identification *	Remarks
5980 A - 5880 A.	CH 5950 A. ($5\nu_3 + \nu_1$)	Previously detected in Saturn, Uranus and Neptune.
5840 A. - 5800 A.	CH 5840 A. ($7\nu_3 - \nu_4$)	Previously detected in Uranus and Neptune.
5760 A. - 5700 A.	CH 5760 A. ($6\nu_3 + \nu_4$)	Previously detected.
5680 A. - 5630 A.	CH 5680 A. ($6\nu_3 + \nu_2$)	Previously detected in Uranus and Neptune.
5540 A. - 5490 A.	?	Possibly CH 5570 A. ($12\nu_4 + \nu_3$)
5440 A. - 5380 A.	CH 5430 A. ($7\nu_3$)	Previously detected.
5340 A. - 5300 A.	?	Possibly CH 5340 A. ($15\nu_4$)
5250 A. - 5100 A.	CH 5210 A. ($6\nu_3 + \nu_1$)	Previously detected in Neptune. Also maybe 5190 A. ( ) and general falloff on violet region of spectrum.

* Identifications are in terms of the four fundamental vibrational frequencies, $\nu_1 = 2915$ cm.$^{-1}$, $\nu_2 = 1520$cm.$^{-1}$, $\nu_3 = 3020$ cm.$^{-1}$, $\nu_4 = 1306$ cm.$^{-1}$. From Adel and Slipher, Physical Review, 1934, 46, 240.

Area 3. Spectrograms of Venus and Jupiter are being reduced. The same type of analysis as in Area one is being used. Another feature that we wish to determine is whether there is a fall off in intensity in various regions of the spectrum due to absorption. At every available opportunity observations are being performed on the near planets: Venus, Mars and Jupiter. Mr. Robert Murphy under the direction of Father Heyden and Dr. Carl Kiess is carrying out this phase of the grant.

Personnel in Grant:

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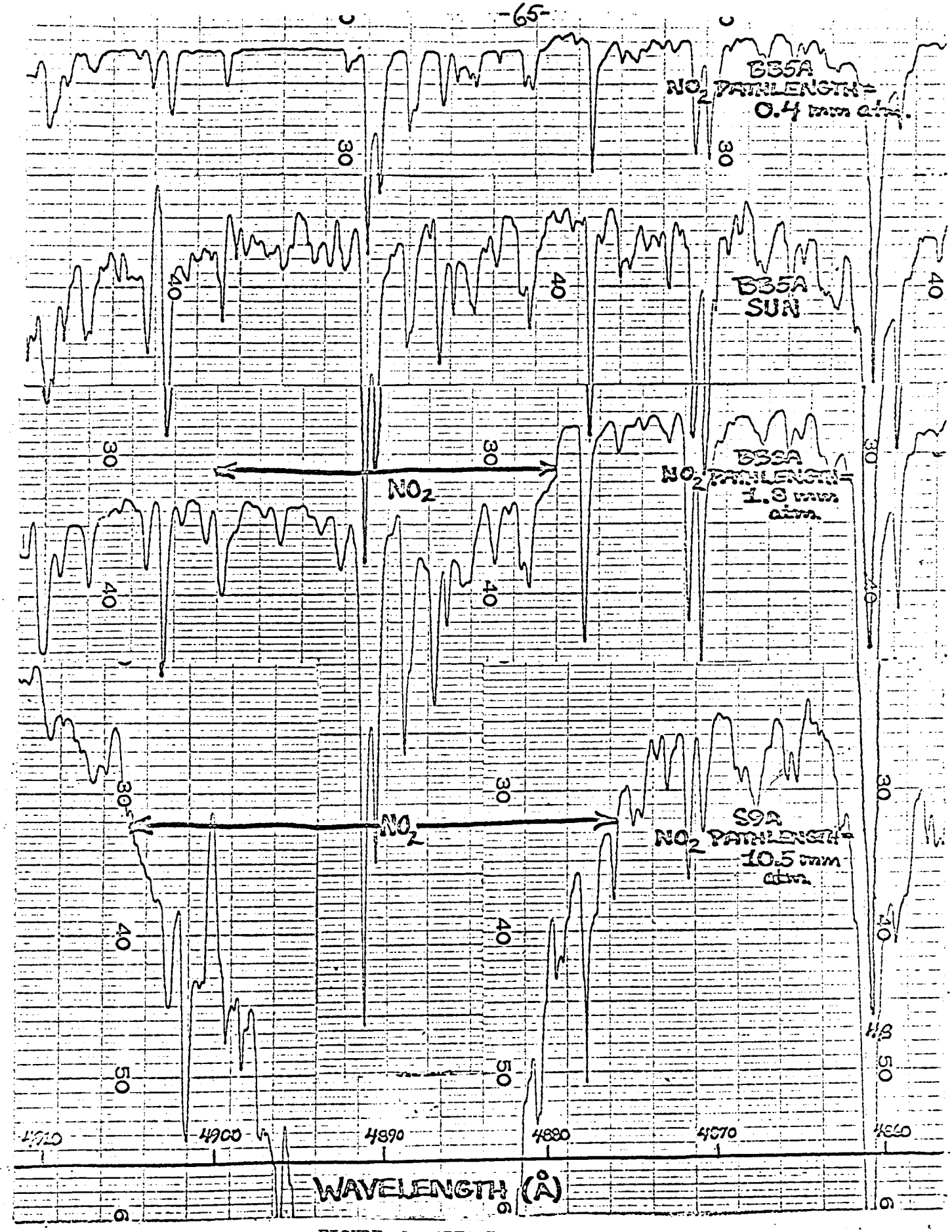

FIGURE 1 AREA I

ABSORPTION BY NO_2 IN SUNLIGHT AT GRADED PATHLENGTHS

T = -5°C

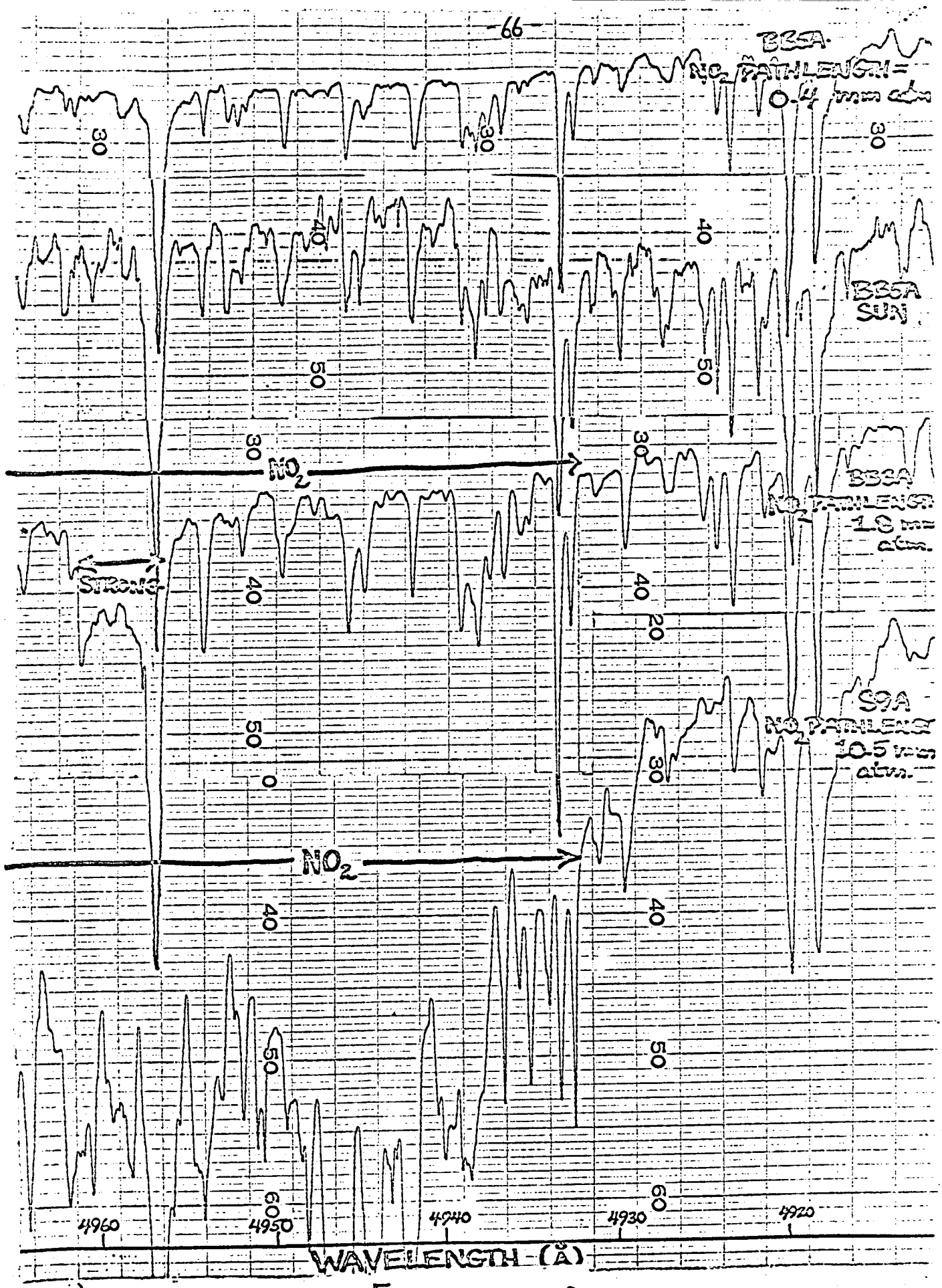

FIGURE 2 AREA I

ABSORPTION E[illegible]NLIGHT AT
GRADED PATHLENGTHS
T = -5°C

TABLE 1 AREA 1

TOTAL PATHLENGTHS OF NO_2
FOR EACH 50 Å REGION*
(See Appendix C)

Wavelength Region	Total Pathlength
4250 Å - 4300 Å	1.8 mm atmospheres
4300 - 4350	1.8
4350 - 4400	4.0
4400 - 4450	5.0
4450 - 4500	5.0
4500 - 4550	5.0
4550 - 4600	6.8
4600 - 4650	6.8
4650 - 4700	6.4
4700 - 4750	3.8
4750 - 4800	5.6
4800 - 4850	3.8
4850 - 4900	3.8
4900 - 4950	3.8
4950 - 5000	3.8
5000 - 5050	3.8
5050 - 5100	3.8

*Plate BB3A = 1.8 mm atm., Plate BB4A = 1.8 mm atm.,
Plate BB5A = 0.4 mm atm., Plate BB6A = 1.0 mm atm.

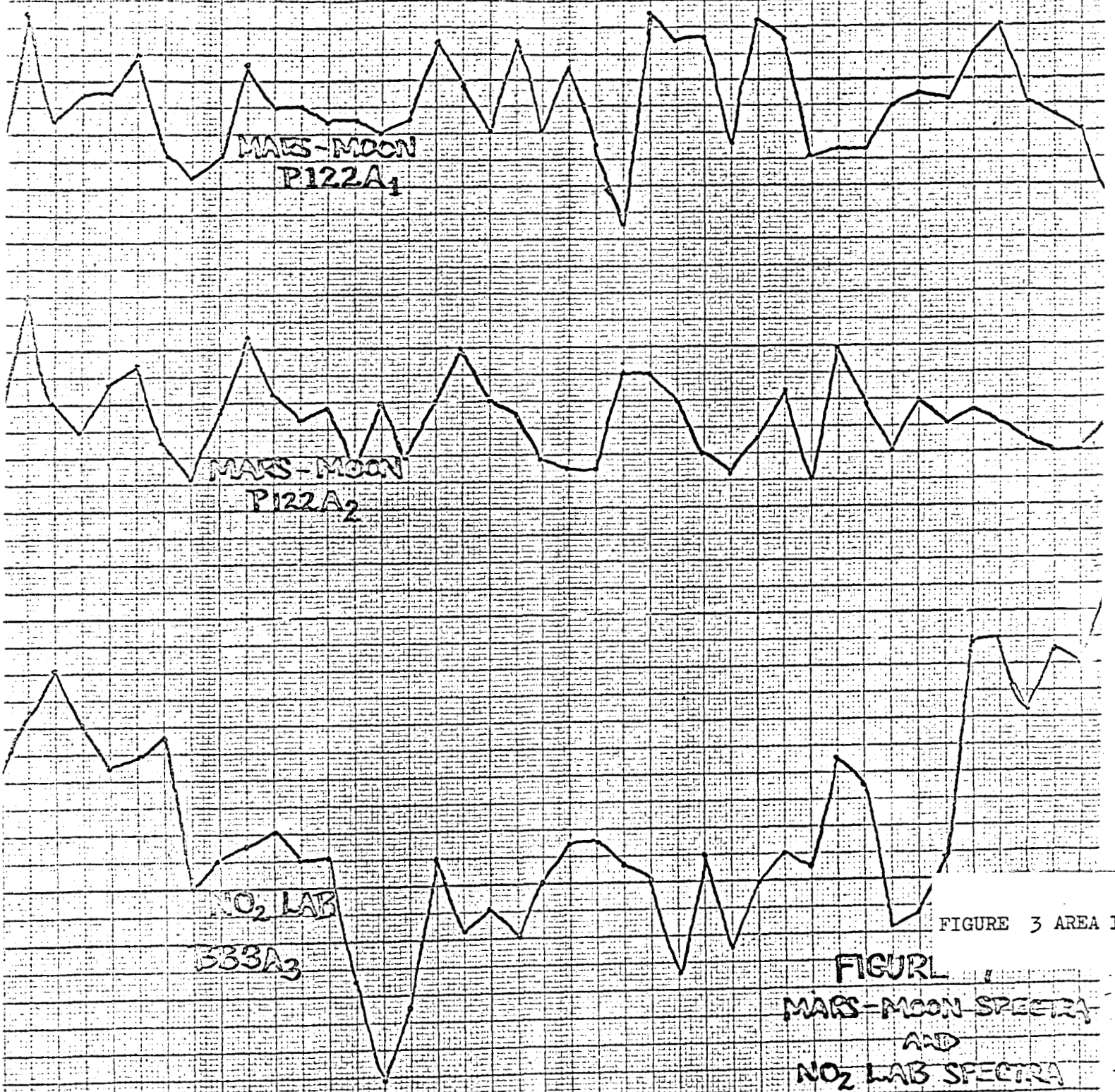

FIGURE 3 AREA 1

FIGURE
MARS-MOON SPECTRA
AND
NO_2 LAB SPECTRA
(COMPRESSED SCALE)

FIGURE I AREA II

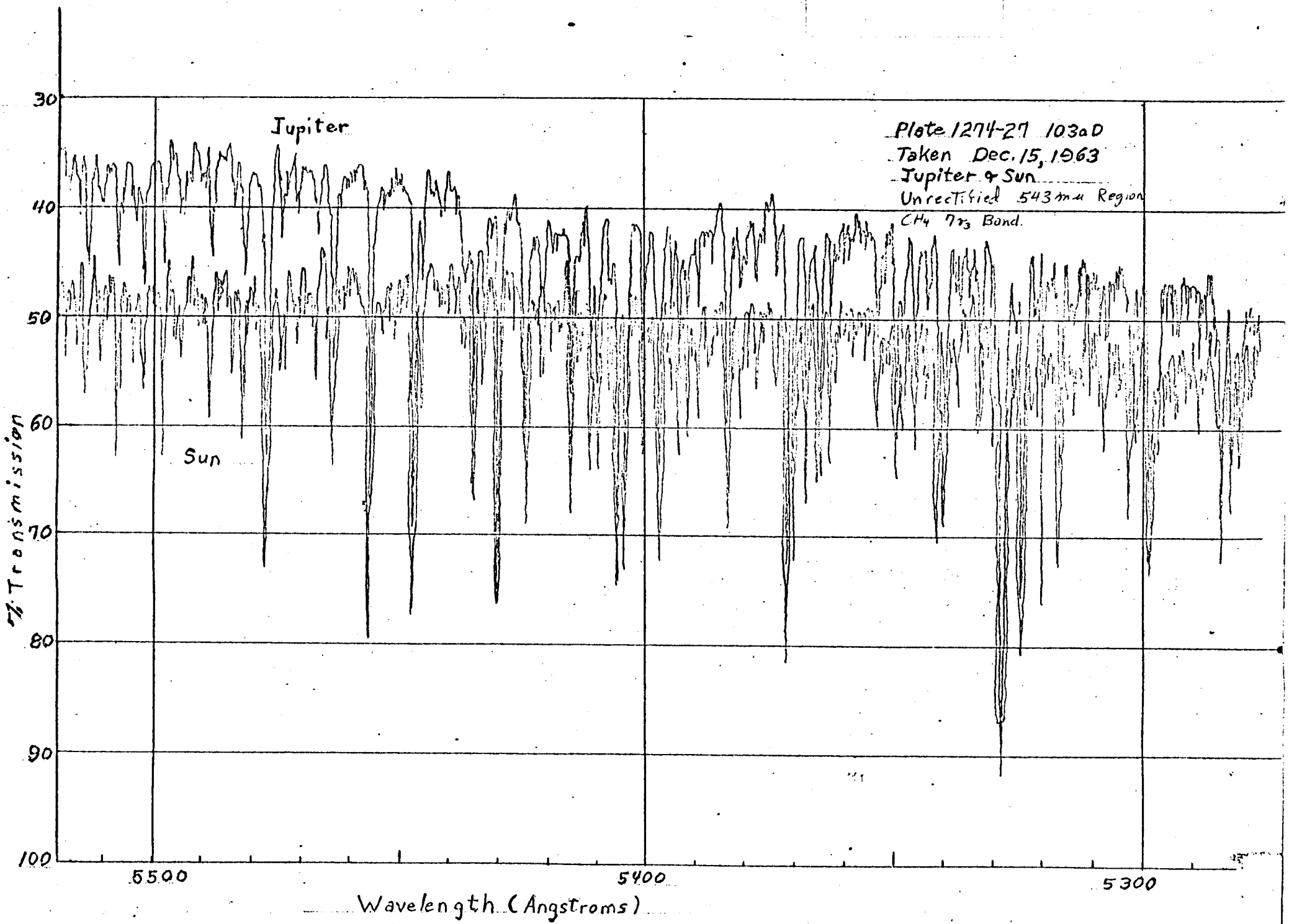

FIGURE 2 AREA II

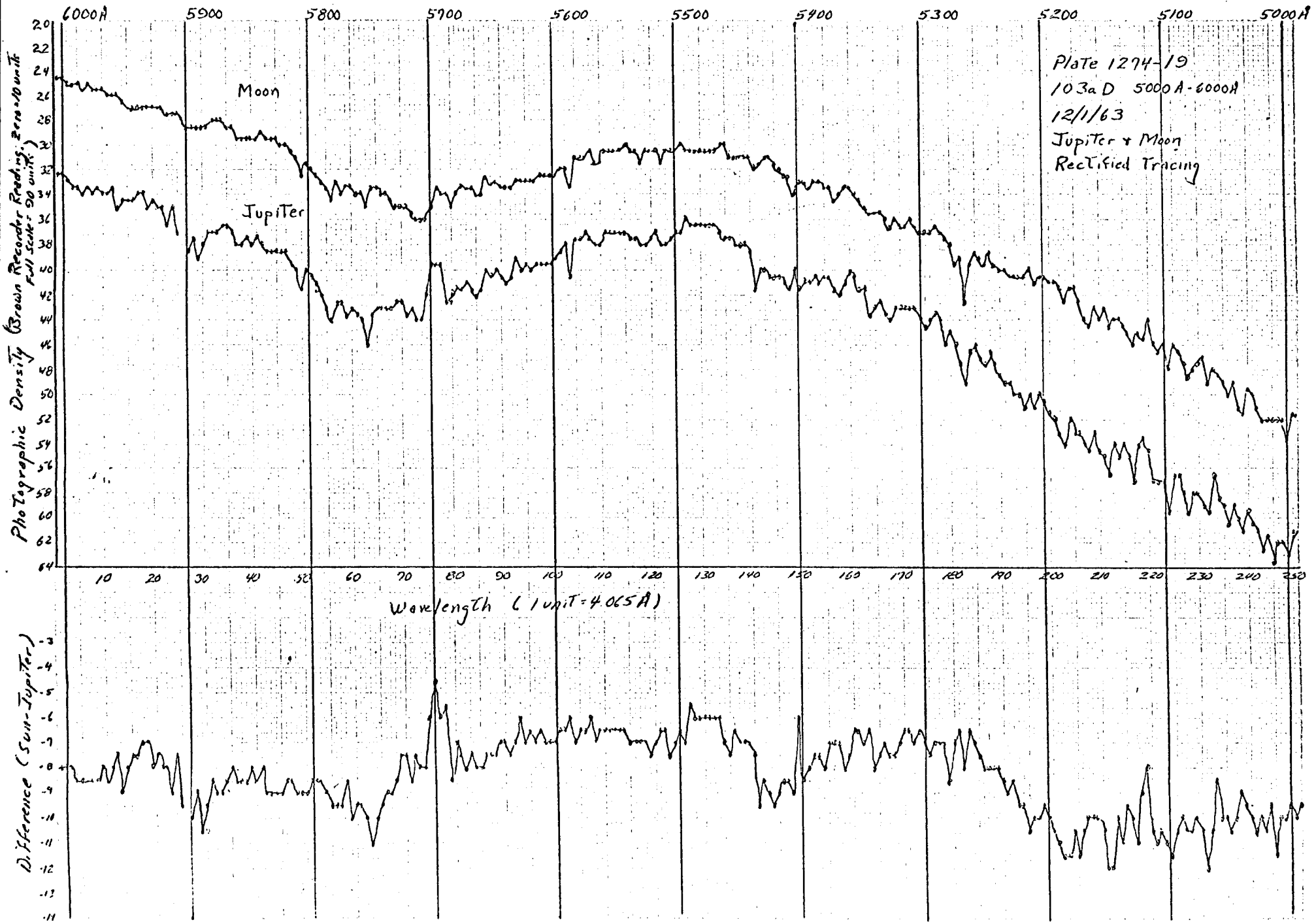

FIGURE 3 AREA II